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DEPARTMENT OF COMMERCE - BUREAU OF MINES

RECOMMENDATIONS OF THE BUREAU OF MINES ON CERTAIN QUESTIONS OF MINE SAFETY[1]

by

The Mine Safety Board[2]

Introduction

Mining men and State officials in their efforts to make mining safer are confronted from time to time with various complicated questions. In recent years these questions have tended to increase with the use of mechanical appliances. Twenty-five years ago electricity had hardly been used in mines. Today there is practically no other means of transmitting energy employed in American mines, except in metal mines where compressed air is used for drilling and small portable hoists. In coal mines there has been a great increase in mechanization and a tendency to concentrate the mining operation, which has resulted in attendant difficulties of ventilation and intensified the danger of coal-dust in bituminous and subbituminous mines.

The answers to the questions which arise are not always obvious, as is shown by the fact that even able, experienced men differ in their opinions of the best way to overcome a particular mining hazard. The difficulty of solving the problems is also demonstrated by the varying provisions in mine safety rules, both in official regulations and in the rules of those mining companies who are endeavoring to do more than follow the letter of the law. Such differences of opinion on the best way of meeting a difficult situation are often found within the same mining organization, and so it has been in the Bureau of Mines.

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[1] The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

[2] G. S. Rice, chief mining engineer, chairman,
O. P Hood, chief engineer, mechanical division,
R. R. Sayers, chief surgeon,
D. Harrington, chief engineer, safety division,
C. W. Wright, chief engineer, mining division.

In order to reduce such differences of opinion and to obtain a generally acceptable decision on any question; a mine safety board was established by the Director of the Bureau of Mines,

> "to consider questions arising within any divisions of the bureau that require a definition of the bureau's collective opinion as to safety practices, safety devices, or safety methods for underground operations or open-pit mining.
> . . . . The approved decisions shall form the basis of teaching and policy for the bureau."

The decisions so far made for issuance publicly relate chiefly to questions on which there have been the greatest differences of opinion and to the best method of meeting certain special or new dangers. Other decisions will be rendered from time to time. Bureau recommendations on general mine-safety problems have already been issued on many questions, the answers to which are obvious or on which there is practical agreement among mine-safety men. These are contained in numerous publications of the bureau, and those relating to coal-mine safety are discussed in a handbook entitled "Safety in Coal Mining."[3]

All but the last of the following 10 decisions have already been published, but in response to requests they are now issued in assembled form with explanation. Most of them apply to coal mining, but numbers 7, 8, and 10 may also apply to metal and other kinds of underground mining. All of the 10 decisions except 2, 5, and 6 relate directly or indirectly to mine ventilation.

The wording of the decisions makes their application largely self-evident, but a certain amount of additional explanation is here given as to the detailed purposes and reasons for which they have been formulated. All the features covered by the decisions arose in the study of reports made for and by the burea, on mine fires, explosions, and general accidents in mines, and it was found as previously indicated that the different members of the bureau staff were not always in agreement as to the best method to recommend for technical handling of a specific complicated problem. Such questions are referred to the Mine Safety Board and an attempt is made to reach a common opinion.

Where decisions are made they form the basis of the recommendations made by the bureau to those mine managements seeking to follow the best practice in attaining the greatest degree of safety.

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[3] G. S. Rice, Safety in Coal Mining: Bull. 277, Bureau of Mines, 1928, 141 pp.

The decisions will be taken up in their order.

Decision 1, relating to miners' lamps in coal mines

> "The Bureau of Mines recommends:
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> (a) In all coal mines the portable lamps for illumination be permissible, portable, electric mine lamps; and also
> (b) In places where fire damp or black damp is liable to be encountered, a permissible magnetically-locked flame safety lamp for gas detection, or equivalent permissible device, be supplied to at least one experienced employee in each such place; and
> (c) Any employee before being supplied with a permissible flame safety lamp be examined by a competent official of the mine to assure the man's ability to detect gas; and
> (d) All coal mines whether classed as non-gassy or gassy in any part, be supplied with magnetically-locked, permissible, flame safety lamps, properly maintained and in sufficient number for all inspection purposes."

These recommendations were made for the following reasons:

First, miners' electric lamps have been so improved that it is no longer a hardship in coal mining to use a portable permissible electric lamp; in fact it is quite the reverse. All open lamps that may cause fires or explosions should be eliminated.

Second, since no approved electric lamp shows the presence of methane or indicates oxygen deficiency, one experienced employee in every place where such conditions are liable to be found should be provided with a permissible flame safety lamp, or equivalent permissible device, to be used for testing.

Third, that although a permissible flame safety lamp is safe is properly assembled and used, there is a possibility of its being a souce of ignition of fire damp if the lamp is illegally opened in the mine or is dropped and the glass broken or if the lamp is struck by a sharp point. Accordingly the use of the permissible flame safety lamps is limited to testing in the hands of competent and experienced employees who can determine with accuracy and safety the percentage of methane in the air in excess of 1½ or 2 per cent.

Other underground employees would under this decision be provided with portable permissible electric lamps giving an excellent steady light; the good illumination would tend to prevent accidents from falls and other hazards, and would avoid the danger of igniting gas.

Decision No. 2, relating to the kind of explosives to use in coal mining.

> "In the interest of safety the Bureau of Mines recommends that for blasting in coal mines, permissible explosives, fired electrically, be exclusively used; and that as an aid to blasting, all coal which is feasible to cut, should be cut or sheared."

The foregoing decision has reference to the character of the explosives employed for blasting in coal mines. It does not preclude the use also of methods devices, and appliances for blasting in coal mines, which have been approved by th Bureau of Mines and placed on its permissible lists.

Nonpermissible explosives like black blasting powder, dynamite, and special explosives that will not pass the bureau's tests for permissibility, readily ignite fire-damp and coal-dust, and have been the cause of countless explosions. Complaint is sometimes made that permissible explosives are not efficient because they can not be efficiently used in "blasting off the solid." This practice, however, is a highly dangerous one, and should not be used at the expense of safety.

Where coal is properly undercut, sheared, or overcut, blasting can be done efficiently and safely with permissible explosive. The design of coal-cutting machinery has so improved that practically any condition in mining can be met by selection of a suitable cutter and a suitable mining method. At present three-fourths of the coal in the United States is cut by machines. It is estimated that in some coal beds blasting with permissible explosives following cutting makes a few per cent more screenings than if black blasting powder is employed. Even if the estimate is admitted to be correct the bureau believes that no operator is justified in taking the chances of an explosion disaster by using a nonpermissible explosive.

Decision No. 3, defining what the Mine Safety Board considers to constitute a nongassy, a slightly gassy, and a gassy coal mine.

The Bureau of Mines believes that all coal mines are potentially gassy; but for purposes of administration in respect to prevention of explosions and fires, the Bureau recommends the following classification:

Class 1 Coal Mine:	a practically non-gassy mine in which inflammable gas in excess of 0.05 per cent can not be found by systematic search.
Class 2 Coal Mine:	a slightly gassy mine in which
(a)	inflammable gas has been found* but in amount less than 2 per cent in still air in any active or unsealed-abandoned workings; or

(b) inflammable gas can be found, but in amount less than 4 per cent, in some place from which the ventilating current has been shut off for a period of one hour; or

(c) inflammable gas can be found** but in amount less than 1/4 per cent, in a split*** of the ventilating current; or

(d) inflammable gas enters a split*** of ventilating current at a rate**** of not more than 25 cubic feet per minute.

Class 3 Coal Mine: a gassy mine in which inflammable gas is found in amount greater than specified for a Class 2 Coal Mine.

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* By employing an approved flame safety lamp, with flame drawn low, or by employing an approved gas detector, or by sampling and analysis with an approved gas analytical apparatus.

** By sampling and analysis with an approved gas analytical apparatus, or by employing an approved gas detector.

*** If but one continuous ventilating current is employed in a mine this shall be considered a "split" for the purpose of this definition.

**** Determined by sampling, analysis, and ventilating-current measurement.

General Notes Regarding Decision No. 3

The inflammable gas found in coal mines is, with rare exceptions, methane, In coal-mining fields where natural gas is found in lower geologic horizons by deep wells which pass through or near by the coal mines, there have been rare instances of a leakage from the well. Natural gas is chiefly methane - almost always more than 85 per cent is methane - but it usually contains ethane, propane, and traces of butane. Therefore if the latter gases are found in mine air, it is an indication of leakage. The lower limit of explosibility of methane-air mixture when there is turbulance is 5 per cent and of natural-gas-air mixtures with about 10 per cent ethane and associated hydrocarbon gases is 4.6 per cent. The limit therefore varies with the character of mixture.

To determine the proper classification of a coal mine, it is advisable that systematic testing and sampling be done at least three times in a period of not less than 72 hours. All tests and samples of the mine air, except one, must show an inflammable-gas content less than the maximum limit of the class to which the mine is assigned. In other words, a tolerance of one test or analysis may be permitted to provide for a mistake or a very exceptional occurrence.

When a new mine is being opened in a coal field where existing mines are generally gassy, it is common sense to assume that similar conditions will be found in the new mine; the development and equipment of the mines should be based upon the expectation that it will be assigned to Class 3.

There is no more disputed question than that covered by this decision as to what constitutes a gassy (or gaseous[4]) mine. Only a few State regulations give any specific directions for determination of gassiness other than that of whether or not approved flame safety lamps are required. A coal mine is popularly spoken of as a "closed-light" mine or an "open-light" mine.

Such a method of rating a mine as gassy is not satisfactory partly because there is such a great difference in other requirements - in ventilation, in use of electricity, etc. Also it tends to prevent the adoption of the "closed lamp" by many mine operators who do not like to admit that their respective mines are gassy; although this is not a good reason why the operator should not take maximum precautions, it is a practical consideration. The bureau's plan in this decision would get away from the indefiniteness and confusion by specifying in precise terms what it designates as a "nongassy," a "slightly gassy," and a "gassy" mine. The bureau's specifications are founded on a study of thousands of analyses of samples of mine air submitted to the Bureau of Mines laboratory at Pittsburgh.

Decision No. 4, relating to auxiliary fans or blowers in coal mines.

> In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that auxiliary fans or blowers should not be used in coal mines as a substitute for methods of regular and continuous coursing of the air to every face of the mine.

The reason for this decision is the widespread recent use of auxiliary blowers, which are nearly always electrically driven in the United States, as a substitute for the regular coursing of the air by frequent ventilation connections and by use of line-brattices. There is great danger of fire damp accumulating by recirculation of the air, and of igniting it by electrical spark. Further, the auxiliary fan is usually intermittantly used and bodies of fire damp collect.[5] Use of the fan has resulted in a considerable number of explosion disasters.

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[4] Although the word "gaseous" is most generally used in the United States, "gassy" is considered by the bureau as more accurate in meaning. Literally a "gaseous mine" would be one not mining solids. A "gassy mine" is one in which the presence of gas is incidental to the mining operation.

[5] The only justification for its use in a properly ventilated coal mine is for emergency work, as in driving a cross-heading in rock to make a connection with distant workings, and where it is too far to carry the air properly by a line brattice. In such a case the auxiliary fan should be operated continuously 24 hours in the day, and the fan and face of the heading should be frequently inspected. A compressed-air driven fan is recommended. If an electrically driven fan is employed, especial attention should be given to thorough insulation of the wiring and fireproofing in the vicinity to prevent the possibility of a mine fire starting from electrical breakdown or overheating of bearings.

Decision No. 5, relating to the prevention of coal-dust explosions by rock-dusting.

> To prevent the propagation of mine explosions, the Bureau of Mines, Department of Commerce, recommends rock-dusting all coal mines, except anthracite mines, in every part, whether in damp or dry condition. It also recommends that rock-dust barriers be used to sectionalize the mine as additional defense; but these should not be regarded as a substitute for generalized rock-dusting.

NOTE: For detailed specifications as to the kind of rock-dust, amount to use, where to be applied, and method of sampling and testing, see Bureau of Mines Serial 2606 and American Engineering Standards Committee "Recommended American Practice for Rock-Dusting Coal Mines" quoted in Bureau of Mines Information Circular No. 6030.

The rock-dusting method[6] of preventing coal-dust explosions has now been accepted in principle by all of the chief coal-mining countries throughout the world. It was recommended after exhaustive testing in the Bureau of Mines experimental mine in 1913. The method was officially approved by France about 1917. It was officially required by Great Britain in 1921, and in Germany in 1926.

Decision No. 6, relating to sealing all parts of a coal mine which can not be kept well ventilated and inspected.

> In the interest of safety, the Bureau of Mines, Department of Commerce, recommends that in coal mines all entries, rooms, panels, or sections that can not be kept well ventilated throughout or can not be inspected regularly and thoroughly, or that are not being used for coursing the air, travel, haulage, or the extraction of coal, be sealed by strong fireproof stoppings.

In the past the question of sealing has been a much disputed one among mining men. Some have considered that it was highly dangerous to inclose areas in a mine which might fill with a body of gas. The bureau agrees with this point of view, unless the stoppings are strong and fireproof; and by strength is meant strength sufficient to hold the stoppings in place if there should be a heavy fall of roof in an empty or partly empty goaf; suddenly compressing the gas or gas and air mixture.

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[6] The suggested use of bringing in inert dust to neutralize the coal-dust was proposed by William Garforth in 1891, and testing began under his direction in 1908 at the Altofts Colliery, Yorkshire, England. In the United States, testing was begun under the Technologic Branch of the U. S. Geological Survey (later the Bureau of Mines) by G. S. Rice and associates in 1909.

On the other hand the engineers of the bureau find from extensive experience that large room-and-pillar mine in which the pillars are either not extracted at all or not extracted for a long period. The old areas are not generally well ventilated and often can not be inspected because of danger of falls, and that the lack of ventilation is inevitable from the enormous territory which may be opened up. Also these regions act as accumulating places for dangerous dust as well as gas.

The bureau believes that the ideal system of coal mining is to take out only a small percentage of coal on the advance, generally less than 20 per cent, and then to extract the pillars promptly on a systematic line of retreat for the whole mine or for a large panel which may be considered equivalent to longwall retreating. Under such conditions there should be no need of sealing extensive areas of open unused workings.

Decision No. 7, relating to the carrying of "intake" and "return" air currents in separate shafts, slopes, or drifts.

In the interest of safety, the Bureau of Mines, Department of Commerce, recommends:

1. That the main intake and main return air currents in mines be in separate shafts, slopes or drifts.

2. That the main intake shaft lining be of fireproof construction, and there be a minimum amount of inflammable material in or adjacent to the shaft.

The recommendations in this decision are applicable to any kind of underground mining. Engineers of the bureau engaged in mine recovery operations during or following fires in coal and metal mines have experienced great difficulty in controlling ventilation and coping with hazardous conditions caused by placing of the "intake" and "return" currents separated only by a partition, in the same mine opening. Even if the partition is fireproof, the smoke and fumes at the bottom of the shaft or slope will almost inevitably work around into both compartments. Also entrance to either compartment at the surface may be made impossible by flame or smoke.

If a strong explosion in a coal mine reaches a shaft in which a partition separates the intake and the return currents, the partition, even though made of concrete, is sometimes blown out because of the unbalanced explosion pressures in the separated compartments of the shaft.

Generally the two compartments in the same mine opening have been used because they were convenient and possibly reduced the initial expense of opening the mine, but such considerations should have no place in the development of a mine, the lifetime of which may be many years.

A fireproof lining in the main intake shaft is recommended to provide a safe means of exit in the event of an explosion or fire. In the greatest mine fire disaster that has occurred in this country, in which 259 men were killed, the mine fire ignited the lining of the intake shaft as well as of the return shaft and thus prevented the escape of the men.

The best practice today is to have at least three shafts with fireproof lining and to have the main hoisting shaft nearly neutral, with just enough of a fresh-air intake split to keep it properly ventilated.

Decision No. 8, relating to definitions used in coal-mine ventilation regulations, but which may also be applied to ventilation in metal and other mines.

The Bureau of Mines, Department of Commerce, recommends that in coal-mine ventilation the following definitions be used:

1. The term "intake air" and the term "return air" without qualifying adjectives shall be used only to define mechanical movement of the air respectively in an inward or outward direction with reference to the mine as a whole or to any one group of workings.

2. When health and safety are concerned, the term "pure intake air" shall mean:

(a) Air which has not passed through or by any active workings, and (or)

(b) Air which has not passed through or by any inactive workings, unless these are effectively sealed, and

(c) Air which is free from poisonous gas and by analysis contains not less than 20 per cent oxygen (dry basis) and not over 0.05 per cent of inflammable gas.

In the State mining codes there is much ambiguity as to the meaning of different mining terms. Therefore, as a prerequisite to the formulation of better codes, it is advisable to have specific terms.

Decision No. 9, relating to the quantity and quality of air to be furnished in ventilating coal mines.

The Bureau of Mines, Department of Commerce, recommends in coal-mine ventilation practice the following specifications as to unit quantity and quality of air:

1. The quantity in cubic feet of pure intake air flowing per minute in any ventilating split shall be at least equal to 100 times the number of men in that split.

2. The quantity of air entering each unsealed place shall be at least 200 cubic feet per minute and as much more as may be necessary to properly dilute and carry away inflammable or harmful gases which may be present.

3. The air shall be made to circulate continuously to the face in every unsealed place into which an appreciable amount of methane enters.

4. The air in any unsealed place shall be considered unfit for men if it shall be found to contain less than 19 per cent oxygen (dry basis), more than 1 per cent carbon dioxide or a harmful amount of poisonous gas.

5. If the air in any unsealed place, when sampled or tested in any part of that place not nearer than four feet from the face and ten inches from the roof, shall be found to contain:

   (a) more than 1½ per cent of inflammable gas, the place shall be considered to be in hazardous condition and require improved ventilation, and

   (b) if more than 2½ per cent of inflammable gas is found, the place shall be considered dangerous, and only men who have been officially designated to improve the ventilation and are properly protected shall remain in or enter said place.

6. If the air in the split which ventilates any group of workings contains more than 1½ per cent of inflammable gas, these workings shall be considered to be in a dangerous condition and only men who have been officially designated to improve the ventilation and are properly protected, shall remain in or enter said workings.

This decision contains provisions for the quantity of air which must be furnished to each and every man in a mine. First, it recommends that the usual minimum of 100 cubic feet of air per minute shall be furnished each man in the mine, but also that the measurement of the air be made in each ventilating split and not at the foot of the shaft or entrance to the mine or an exit from the mine, as it has been found that in some mines there is a leakage of from 50 to 75 per cent or more between the fan and the working faces.

The second provision is to take care of the condition where workings are left open, and to call for a ventilation by the same amount of air as provided in the active working places. To obviate the need for this additional ventilation, the remedy would be to seal off unused workings as recommended under Decision 6.

The third provision is to insure that in a gassy place the ventilation will be carried into the face of every active and inactive open working place by means of crosscuts and line-brattices beyond the last open crosscut and thus will prevent accumulations of fire damp.

The fourth provision refers to the quantity of the air; that is, if the ventilation called for in provisions one and two is not adequate, additional quantities of air should be furnished to the respective places.

The fifth provision is to define the minimum amount of inflammable gas which may be considered to be a dangerous hazard in a working place; another specification defines the limiting percentage of inflammable gas in places from which the men should be withdrawn.

The sixth provision concerns the limiting percentage of inflammable gas in a ventilating split that is so dangerous as to require the withdrawal of the men from the workings.

Decision No. 10, relating to ways of escaping from a mine

The Bureau of Mines, Department of Commerce, in the interest of safety in all underground mines, recommends:

1. That every underground mine shall have two or more ways of escape to the surface, so arranged and equipped that men can escape quickly.

2. Such ways of escape shall be so separated by at least 50 feet of natural ground throughout their length that damage to one from any source shall not thereby lessen the effectiveness of the other as a means of escape.

3. (a) Where the way of escape is a shaft which is steeper than 45 degrees from the horizontal, it shall have incombustible walls or lining and contain no fire hazard from the surface to the lowest level.

   (b) Where the way of escape is a drift or slope which is inclined less than 45 degrees from the horizontal, the incombustible walls, or lining, and freedom from fire hazard shall extend at least 200 feet from the entrance.

4. Where but one way of escape has incombustible walls or lining, it shall be the normal intake airway.

5. Not more than 10 men shall be employed in any part of a mine on any one shift until a second way of escape from that part has been provided.

Decision 10 is intended to apply to any kind of underground mine.

The first provision is one which is to be found in practically all State mining codes, except that as a rule requirements are not made for the quick escape of men, aside from the satisfactory means of escape. Since the establishment of the Bureau of Mines there have been numerous accidents in places from which men were unable to escape by satisfactory means because there were not adequate arrangements for their getting out quickly, as by hoist in a deep shaft.

The second provision is to establish a minimum distance between ways of escape to insure that a fire or explosion which blocks one way would not at the same time render the other means of escape difficult or impossible of access.

The third provision relates to making fireproof the shaft, drift, or slope used as an escapeway.

The fourth provision is to insure that where there is only one way of escape that is fireproofed, it shall be used as the normal intake airway. This clause is also covered in a different manner by the second clause in Decision 7.

The fifth provision is to prevent the employing of any considerable group of men in any part of any mine where there are not two ways of escape, and limits the group to 10 men on any one shift exposed to a hazard, until a second way shall have been made by sinking shafts or slopes, or driving drifts or crosscuts from the surface or from other workings.

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